ELECTRICAL ACTIVITY OF THE DIENCEPHALON OF THE FROG

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The electrical phenomena of the frog's brain have for a long time attracted the attention of the investigator [3, 4, 7-9]. It has been found that each part of the brain is characterized by its own particular type of spontaneous electrical activity [7], and that this activity is slight and is increased by the action of various afferent stimuli.

The phenomena taking place at the base of the brain have been studied less than the others. This problem is rendered particularly complex by the fact that in this case, besides the currents due to the brain itself, currents may also be recorded from glands (especially the pituitary). The possibility that currents may be generated by glands was originally suggested by DuBois Reymond [16], and it was subsequently proved for the glands of internal secretion [10, 12, 15, 21]. One of the earliest accounts of the action currents of the pituitary was given by Hasama [18].

The present paper gives the results of a study of the changes in the constant potential of the diencephalon of the frog.

EXPERIMENTAL METHOD

Experiments were carried out on male frogs (Rana temporaria) wieghing about 50 g, immobilized with ditilin (succinylcholine) in a dose of 0.1-0.2 ml of the 1% solution. The frogs were kept in a refrigerator at 4-8°; one day or several hours before the experiment they were placed in an aquarium with a very small amount of water at room temperature; in summer the temperature reached 24-26°. The potentials were detected with unipolar nonpolarizing S-shaped zinc amalgam electrodes and the e.m.f. was recorded on a Disa 51-B-00 twin-beam cathode-ray oscillograph, fitted with amplifiers with a wide transmission bank (lower limit—0), and a photorecording system; a downward deflection of the beam corresponded to electronegativity. One electrode was placed on the brain, the other on the skin of the right thigh, inactivated by coagulation. The S-shape of the electrodes protected the tissues against leakage of the solution of zinc sulfate and ensured a large radius of movement of the electrode. Contact between the electrodes and the tissue was effected through a saline bridge by means of a wick. The animal was placed in a humid chamber. The bioelectrical activity was investigated in the region of the neurohypophysis. The approach to the pituitary was made in the usual manner: the sphenoid bone covering the gland was resected. Some experiments were carried out in association with stimulation of the superior sympathetic ganglia. Altogether 72 experiments were performed.

EXPERIMENTAL RESULTS AND DISCUSSION

Series I: recording of biopotentials from the posterior lobe of the pituitary (neurohypophysis) following removal of the anterior lobe, and from the region of the tuber cinereum and infudibulum (the whole of the pituitary removed). The constant potential in this region was usually positive when recorded in these conditions. Its magnitude varied depending on the temperature at which the animals were kept (from 10-15 mV in winter to 25-28 mV in summer). In these experiments rhythmic activity was observed in the region of the hypothalamus and posterior lobe of the pituitary, in the form of a wave-like negative or positive fluctuation of the constant potential. In the winter period this activity was less intensive. For example, when the sensitivity of the amplifier used lay between 1.2 mV (per scale division) and 2-3 mV (mean 1.8 mV/division in December and the first half of March), in 57% of the experiments waves were observed with an amplitude of between 0.1-0.2 and 0.4 mV, a duration of 6-17 sec, and a frequency of 1-2 per 5 min. In January and February hardly any waves were observed. From the second half of March

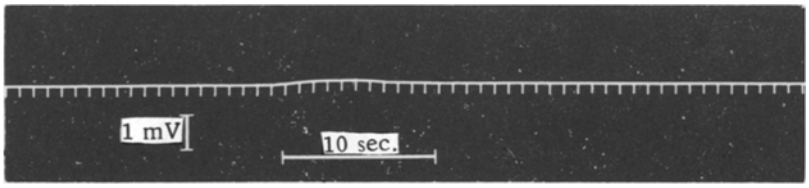

Fig. 1. Recording of biopotentials from the posterior lobe of the pituitary.

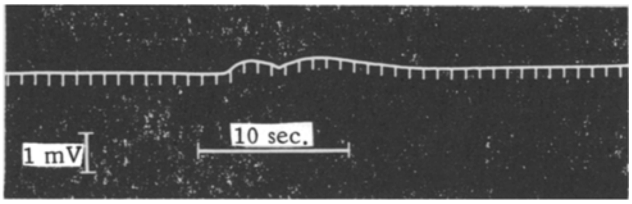

Fig. 2. Recording of biopotentials from the hypothalamus (region of the tuber cinereum and infundibulum).

this activity increased and it was seen in a larger number of experiments, but the maximum was attained during the summer months (92%): the period of oscillation was 35-50 sec, amplitude up to 1 mV, and the rhythm of the waves 1/min or more. A slow rise and slow fall of the e.m.f. were characteristic. These experiments were performed 30-40 min after the operation on the pituitary and observations and phororecordings were made for a period of $1\frac{1}{2}$-2 h (Figs. 1, 2). In some experiments the recordings were made 3-5 and 8 h after the operation: the observed effect was much weaker.

Series II: recording of biopotentials from the same regions 24 h after the operation (10 experiments). In these cases when the potentials from the posterior lobe of the pituitary were recorded usually a weak activity was found, and in the recordings from the tuber cinereum and infundibulum the waves were less frequent and in some cases completely absent.

The fluctuations of e.m.f. which were observed were very similar in character to the biopotentials of the glands, as described in the literature: slow waves with a duration of a few seconds or more, gradually reaching a maximum and then diminishing gradually. It may be asked whether the observed phenomenon may have been the result of the action of coincidental factors, such as: 1) other unrelated electrical fields (heart, respiratory center); 2) changes in the e.m.f. as a result of movements of the animal (movements of respiration, of the tongue, of swallowing, etc.).

It should be noted that although the ECG was superimposed on our recordings (because of the properties of the amplifier), changes in the cardiac activity had no effect on the appearance or the character of the observed activity. The same remarks apply also to the respiratory center, the fluctuations of the e.m.f. of which have a short period [5].

The animal's movements may also cause changes in the e.m.f., but these changes (which were specially recorded) are different in character, short in duration (1-3 sec), and are almost completely abolished by curarization. Hence, the possible fluctuations in e.m.f. dependent on the existence of irrelevant electrical fields are characterized by a short period of oscillation, and evidently are unrelated to the phenomena which were observed.

In the experiments of series III the effect of stimulation of the sympathetic ganglia on the bioelectrical activity of the hypothalamic and pituitary region was studied, for according to data in the literature the sympathetic nervous system is one of the mechanisms activating the pituitary [10, 12]. For this purpose the superior cervical sympathetic ganglia were stimulated with a 0.5-0.25% solution of nicotine. The ganglia were exposed through the mouth by the method described by Aleksanyan and Mikhaleva [2]. During the experiment swabs soaked in nicotine were applied to the ganglia. As a rule nicotine was applied against the background of existing rhythmic waves, after which the waves usually disappeared. In most cases the waves returned after 10-20 sec, sometimes after 60-70 sec, and at times they were actually stronger than before the application of nicotine to the ganglion (Fig. 3). Much more rarely after stimulation rhythmic waves of e.m.f. appeared when hitherto they had been absent.

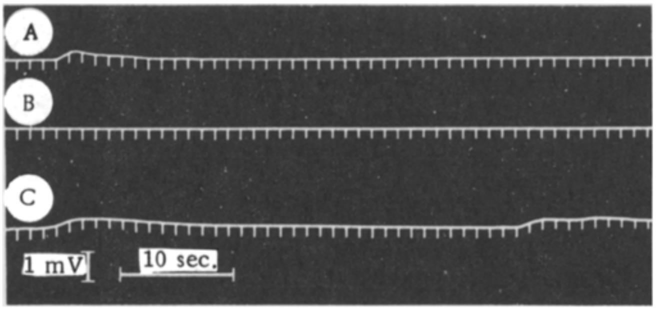

Fig. 3. Action potentials of the posterior lobe of the pituitary. Fluctuations of biopotential before stimulation of the sympathetic ganglia with nicotine (A), and 5 min (B) and 20 min (C) after stimulation.

The slow rhythmic changes of constant potential, which bore an obviously seasonal character, were such as to suggest that they reflected hormonal activity, a characteristic feature of the region of the hypothalamus and pituitary. V. Yu. Chagovets [11] originally remarked that "waves of electrical potentials of glands may be used as a very sensitive indicator of the physiological process being carried on in them."

The literature on the electrophysiology of the glands of external and internal secretion shows that the waves of potentials of these glands in fact reflect their secretory activity and may be observed in two forms: 1) as slow waves lasting a few seconds or a few tens of seconds and observed once in the course of the experiment. Such waves have been described during the study of the action potentials of the frog's pituitary [18], the rabbit's thyroid [19], and the cat's submaxillary gland [22]; 2) as very prolonged changes in the potential of the gland—lasting ½ h or more, as has been observed in connection with the secretory activity of the glands of the stomach [12, 13] and in experiments on the pancreas [7]. Fluctuations in the e.m.f. of glands may be both positive and negative, depending on many factors. The negative and positive fluctuations in e.m.f. observed in the present experiments were possibly associated with the presence of groups of cells in the region under examination with different functional polarities and with predominance of the activity of one particular group at the moment of recording.

We found no data in the literature concerning spontaneous rhythmic activity of glands of the type observed in our experiments, for these waves were present both in the presence of an intact anterior lobe and in its absence. Clearly the anterior lobe of the pituitary plays no part in its genesis. Removal of this lobe is so easy to perform that there is no question of the possibility that part of it may have been left behind. After removal of the posterior lobe, when recordings of the biopotentials were made directly from the region of the tuber cinereum and infundibulum, the activity also remained, and sometimes it was actually intensified for a short time. It must be remembered here, however, that removal of the posterior lobe is more difficult than removal of the anterior, and without special histological investigation it cannot be determined whether the removal has been complete. Even in small amounts, pituitary tissue is capable of secretory activity. In experiments conducted 24 h after removal of the posterior lobe, in some cases the fluctuations of e.m.f. were absent. However, this may be attributed, not only to absence of the posterior lobe, but also to depression of the function of the hypothalamic region as a result of the postoperative trauma. In connection with the foregoing facts interesting facts have been reported concerning the action potentials of the isolated diencephalon of the ox and part of the pituitary following administration of various nerve poisons. It has been found that under these circumstances the isolated posterior lobe of the pituitary exhibits slow action potentials, while the diencephalon, on the other hand, reacts with fast rhythmic waves [20].

Comparison of our findings with those obtained by Hasama [18-20] and other authors suggests that the slow rhythmic waves observed in our experiments owe their origin largely to the posterior lobe of the pituitary. However, bearing in mind the close anatomical and functional relationships between the posterior lobe and the hypothalamus, at this stage of the investigation all that can be said is that the observed fluctuations of e.m.f. belong to only one of these formations. Important confirmation of the possibility that the observed phenomenon may be related to the hypothalamic region has been given by the work of N. A. Aladzhalova [1], who used the method of implanted electrodes in rabbits and recorded irregular "very slow" waves of constant potential in the posterior and medial hypothalamus, when the frequency of the fluctuations of the e.m.f. reached 6-10/min.

N. A. Aladzhalova suggests that the very slow waves of constant potential (VSW) which she observed are a reflection of the "ascending colloid" secretion of the hypothalamic formations, exerting its influence on certain structures of the cortex, as revealed by the appearance of a VSW in the cortex with a slower rhythm. No direct parallel can be drawn, however, between our findings and those mentioned above, for both the method and the results were different. We suggest that the phenomena which we observed may be related, not to the ascending colloid, but to the ordinary granular secretion of the region under investigation. The dual effect of stimulation of the sympathetic nervous system on the function of the structures which it innervates is described widely in the literature [14], so that the results of the experiments in which the sympathetic ganglia were treated with nicotine do not, in our opinion, conflict with the hypothesis that the slow rhythmic waves of e.m.f. originate in fact in the region of the hypothalamus and pituitary, and they give evidence of the possible role of the sympathetic innervation in their genesis.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. ***Some or all of this periodical literature may well be available in English translation.*** **A complete list of the cover-to-cover English translations appears at the back of this issue.**